hibited to the Academy by Professor Henry, on which were indicated the beginning and progress of some remarkable changes of weather.) From these maps it appears that the great disturbances of the atmosphere which spread over the surface of the United States enter our territory from the possessions of the Northwest Company, about the sources of the Saskatchewan, at the base of the Rocky Mountains, and are thence propagated south and east until in many instances they spread over the whole of the United States and probably a large portion of the British Possessions.

For example, the great depression of temperature which occurred in January of the present year [1859] and which will be remembered by every one as the most marked cold period of the season entered the territory of the United States at the point before mentioned on the 5th of January, and on the 6th reached Utah, on the 7th Santa Fe, and on the 8th the Gulf of Mexico, and passing onward it was felt at Guatemala on the 10th. While it was advancing southward it was spreading over the continent to the east. On the 7th it reached the Red River settlement, and all places under the same meridian down to the Gulf of Mexico. It reached the meridian of Chicago on the 8th, the western part of the State of New York on the 9th, New England on the 10th, and Cape Race on the 13th. It moved with about equal velocity over the Southern States, and was observed at Bermuda on the 12th.

The remarkable frost of last June, so far as it has been traced, had the same origin, and followed the same eastward course. The fact was also illustrated, by the maps before mentioned, that the warm periods which have occurred in past years have followed the same law of progression, and consequently their approach could have been announced to the inhabitants of the Eastern States several days in advance, had a proper system of telegraphic dispatches been established.

The value of the telegraph in regard to meteorology has been fully proved by the experience of the Smithsonian Institution. The Morse line of telegraph has kindly furnished the Institution during the last twelve months [1858 and 1859], free of cost, with a series of daily records of the weather, from the principal stations over the whole country east of the Mississippi River and south of New York. In order to exhibit at one view the state of the weather over the portion of the United States just mentioned, a large map is pasted on a wooden surface, into which, at each station of observation, a pin is inserted, to which a card can be temporarily attached. The observations are made at about 7 o'clock in the morning, and as soon as the results are received at the Institution, an assistant attaches a card to each place from which intelligence has been obtained, indicating the kind of weather at the time; rain being indicated by a black card, cloudiness by a brown one, snow by a blue one, and clear sky by a white card.

This meteorological map is an object of great interest to the many persons from a distance who visit the Institution daily. All appear to be specially interested in knowing the condition of weather to which their friends at home are subjected at the time. But the value of the map is not confined to the gratification of this desire. It enables us to study the progress of storms, and to predict what changes in the weather may be expected at the east from the indications furnished by places farther west. For example, if a black card is seen in the morning on the station at Cincinnati, indicating rain in that city, a rainstorm may confidently be expected at Washington at about 7 o'clock in the evening. Indeed, so uniformly has this prediction been verified that last winter [1858–59] the advertising in the afternoon papers of the lecture to be delivered at the Institution that evening was governed by condition of the weather in the morning at Cincinnati, a rainy morning at the latter inducing a postponement of the lecture.

It must be evident from the facts given that if a system of telegraphing over the whole country east of the Rocky Mountains were established, information could be given to the Middle and Eastern States of the approach of disturbances of the atmosphere of much value to the agriculturist, the ship owner, and to all others who transact business affected by changes of weather, as well as of importance to the invalid and the traveler. Indeed, with a proper combination of the lines now in operation, daily intelligence might be obtained in the city of Boston which would be of the highest interest to its inhabitants. Professor Henry mentioned Boston in particular, because this city is so situated that the storms, both of the southern and western class, reach it after they have been felt in New York and in other places which are not as far east and north. It is necessary to remark that the same use of the telegraph is in a measure inapplicable to the inhabitants of western Europe, since they live on the eastern side of an ocean and can not be apprised of the approach of storms from the west. For the same reason the general laws of storms are more conveniently studied by the meteorologists of this country than by those of Great Britain and France.

It should be distinctly understood that the remarks which have been made in this communication relate to the more violent changes of the weather which occur in autumn, winter, and spring. The thunder showers which occur almost daily during the warm weather in summer have somewhat of a local character, and commence at the same time, and frequently at the same hour, for several days in succession, at the same and different places, but wherever they commence they move eastward over the country until they are exhausted.

Professor Henry also spoke of the facts collected in regard to the nature of American storms, and their connection with the two great aerial currents continually flowing over the temperate zone. He considered that the great changes of the weather are principally due to the gradual production of an unstable equilibrium in the two currents, by the accumulation of heat and moisture in the lower.

He spoke in high terms of the importance of the labors of Mr. Espy in developing the theory of the upward motion of air, and the evolution of latent heat in the production of storms.

In reply to a question as to the possibility of crossing the Atlantic in a balloon, the Professor stated that he had little doubt, if the balloon could be made to retain the gas, and to ascend into the upper current, it would be wafted across the ocean in the course of three or four days. If it descended into the lower current, it would be carried to the north of east; and if it continued in the upper current, it would reach Europe south of the same point. The course could be changed, within certain limits, by ascending and descending from one current to the other. The late balloon voyage from St. Louis to Jefferson County, N. Y., was of interest in confirming the theoretical direction of the great lower current of this latitude.

## BROUN'S LAW OF WINDS AND CURRENTS.

In December, 1871, while in the midst of forecast duty and of an intense study of every observational feature of atmospheric circulation, the Editor had the good fortune to receive a visit from the veteran aeronaut, Samuel A. King, from whom he obtained the loan of a volume of newspaper cuttings describing many of his aeronautical voyages. From this volume he prepared for Mr. King the tables presented on December 16, 1871, published on pages 36–38 of the Bulletin of the Philosophical Society of Washington, Vol. I. The object of this compilation was to show the direction of each of the currents of air into which the balloon ascended on the respective voyages. On that occasion the Editor called attention to the fact that it is rare to find an upper current in a direction opposed to the lowest or surface wind, the deviations being usually between 90° and 135°, but as the balloon ascended but little more than 10,000 feet these records only give us an insight into the nature of the lower system of currents that precede extended storms; the ascensions were made by preference only in the settled, pleasant weather attending areas of high pressure and in the warmer season of the year.

Even before this publication the Editor had been studying the direction of upper clouds, as telegraphed daily to Washington, and displayed on the maps used by him in making up the tridaily "probabilities" of the Signal Service, and had perceived the general and almost invariable rule that the upper cloud directions lie to the right of the lower clouds, and the latter to the right of the winds. In a letter of February, 1872, he said:

> The upper clouds move toward a point on the right-hand side of that toward which the surface winds blow; the angle between these two directions varies from 0 to 180° but is, in a majority of cases, 90°.

This generalization leads to a very simple theory of the upper currents within areas of low pressure, the so-called cyclonic inflow of the winds below and anticyclonic outflow of the cirrus clouds above.

A few months later the Editor stated: "This is evidently only another way of saying that the upper clouds move away from areas of low pressure," and illustrated this by the following five tables for the motions of cirrus and cumulus clouds prepared for Washington, during the months of January to June, 1872.

Tables I and II show, respectively, the number of times that clouds were observed from a given direction when a given surface wind prevailed. The compilation of such tables is a mere matter of counting. Thus, with a northwest wind, cirrus clouds were observed moving from northwest 16 times out of the whole 118 cases.

Table III shows how much any cloud direction deviates to the right (plus) or to the left (minus) from any wind direction. Applying this general table to the data in Tables I and

II, we get the results given in Tables IV and V, which show that the average amount of deviation of the cirrus cloud to the right of the wind is 27.6°, while the average amount for the cumulus clouds or lower currents is only 4.6°.

*Comparison of directions of movements of clouds and winds, at Washington, from January to June*, 1872.

I.—CIRRUS CLOUDS.

| Wind. | Clouds. S. | SW. | W. | NW. | N. | NE. | E. | SE. | Sums. |
|---|---|---|---|---|---|---|---|---|---|
| S. | 6 | 9 | 5 | 6 | ..... | ..... | 2 | 1 | 29 |
| SW. | ..... | 8 | 1 | 1 | ..... | 1 | 1 | ..... | 12 |
| W. | ..... | 2 | 7 | 1 | ..... | ..... | ..... | 1 | 11 |
| NW. | ..... | 5 | 3 | 16 | 2 | 4 | 1 | 3 | 34 |
| N. | ..... | 2 | 3 | 1 | 2 | ..... | ..... | 2 | 10 |
| NE. | ..... | ..... | ..... | ..... | ..... | 2 | 1 | ..... | 3 |
| E. | 1 | ..... | 1 | ..... | ..... | 1 | ..... | ..... | 3 |
| SE. | ..... | 4 | 3 | 6 | ..... | 1 | ..... | 2 | 16 |
| Sums. | 7 | 30 | 23 | 31 | 4 | 9 | 5 | 9 | 118 |

II.—CUMULUS CLOUDS.

| Wind. | Clouds. S. | SW. | W. | NW. | N. | NE. | E. | SE. | Sums. |
|---|---|---|---|---|---|---|---|---|---|
| S. | 5 | 9 | 4 | 2 | 1 | 3 | 1 | ..... | 25 |
| SW. | ..... | 7 | 5 | ..... | ..... | ..... | ..... | ..... | 12 |
| W. | ..... | 6 | 18 | 8 | ..... | ..... | 3 | 2 | 37 |
| NW. | 2 | 10 | 14 | 54 | 1 | 2 | 3 | 5 | 91 |
| N. | ..... | 1 | 11 | ..... | 3 | 1 | ..... | ..... | 16 |
| NE. | ..... | ..... | ..... | 5 | ..... | 3 | ..... | ..... | 8 |
| E. | ..... | ..... | 1 | ..... | ..... | ..... | ..... | ..... | 1 |
| SE. | ..... | 6 | 7 | 1 | ..... | 1 | ..... | 5 | 20 |
| Sums. | 6 | 39 | 60 | 70 | 5 | 10 | 7 | 12 | 210 |

III.—GENERAL TABLE FOR COMPUTING THE DEVIATION OF CLOUDS FROM WIND IN TERMS OF 45° AS UNIT ANGLE.

+ = to the right. − = to the left. x = directly opposite, or 4 times 45°.

| Wind. | Clouds. S. | SW. | W. | NW. | N. | NE. | E. | SE. |
|---|---|---|---|---|---|---|---|---|
| S. | 0 | +1 | +2 | +3 | x | −3 | −2 | −1 |
| SW | −1 | 0 | +1 | +2 | +3 | x | −3 | −2 |
| W. | −2 | −1 | 0 | +1 | +2 | +3 | x | −3 |
| NW. | −3 | −2 | −1 | 0 | +1 | +2 | +3 | x |
| N. | x | −3 | −2 | −1 | 0 | +1 | +2 | +3 |
| NE. | +3 | x | −3 | −2 | −1 | 0 | +1 | +2 |
| E. | +2 | +3 | x | −3 | −2 | −1 | 0 | +1 |
| SE. | +1 | +2 | +3 | x | −3 | −2 | −1 | 0 |

IV.—CIRRUS CLOUDS. JANUARY TO JUNE, 1872.

Summary of deviations.

| | Times. | |
|---|---|---|
| Clouds move with wind | 43 | |
| Clouds deviate 45° to right | 14 | |
| Clouds deviate 90° to right | 15 | 41 |
| Clouds deviate 135° to right | 12 | |
| Clouds opposed to wind | 11 | |
| Clouds deviate 135° to left | 4 | |
| Clouds deviate 90° to left | 11 | 23 |
| Clouds deviate 45° to left | 8 | |
| | 118 | |

V.—CUMULUS CLOUDS. JANUARY TO JUNE, 1872.

Summary of deviations.

| | Times. | |
|---|---|---|
| Clouds move with wind | 95 | |
| Clouds deviate 45° to right | 24 | |
| Clouds deviate 90° to right | 12 | 48 |
| Clouds deviate 135° to right | 12 | |
| Clouds opposed to wind | 11 | |
| Clouds deviate 135° to left | 8 | |
| Clouds deviate 90° to left | 28 | 56 |
| Clouds deviate 45° to left | 20 | |

It was on the basis of such computations as this that the Editor framed a recommendation embodied in his paper on the "Marine nephoscope and its usefulness to the navigator" (see the Report of the International Meteorological Congress at Chicago in 1893, Part I, p. 163):

As a result of the work that has hitherto been done on this subject, I think we may for the present adopt the general rule that between the winds blowing spirally inward and the upper clouds blowing spirally outward there is an intermediate layer of the so-called lower clouds, whose motion is very nearly along a circular arc, and that the mariner may more safely locate the storm center as being in a line perpendicular to the motion of the lower clouds, rather than to rely entirely upon the surface winds.

Even Redfield had stated that the average inclination of the lower clouds to the circle around the storm center, as deduced from his own observations in New York City, was less than the inclination of the winds and averaged only 7°.

The generalization above given by the Editor was, in fact, often expressed by him in a more general way, as follows, viz, that the higher we ascend in the atmosphere, so much the more does the direction of the wind or currents deflect to the right, a rule that has, perhaps, sometimes been called Ley's law.

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The difference in direction of the upper and lower currents of air, which is sometimes referred to as Ley's law, was, we believe, first published by him in his Laws of the Winds Prevailing in Western Europe, Part I, London, 1872. On page 149 he says:

Owing to this and other difficulties, no attempts appear to have been hitherto made to systematize the results of upper current observations with a view to ascertain the relations existing between the directions and velocities of such currents and the distribution of pressures at the earth's surface.

He then gives some account of his own observations on the true cirrus clouds, as observed by him for more than ten years in England, and shows that they demonstrate a systematic difference from the lower currents, which latter obey the so-called Buys-Ballot law, and that, in general—

In whatever position we stand relatively to the centers of highest or lowest pressures, we find the motions of the upper current more commonly inclining from the lower toward the higher pressures than in the contrary direction.

Or, again:

The number of instances in which the upper currents incline from low to high pressures and that in which they incline from high to low pressures is about as four to one.

Or, again, page 156:

The higher currents of the atmosphere, while moving commonly in a general way with the highest pressures on the right of their course, yet manifest a distinct centripetal tendency over the areas of high pressure and a distinct centrifugal tendency over the areas of low pressure. This tendency is the more noticeable as being the contrary of that which prevails in the motion of the surface winds. The latter, when deviating from a parallelism with the isobarics, incline, in a large percentage of examples, toward lower and from higher pressures.

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About 1881 the Editor discovered that in 1846 the distinguished J. Allan Broun had anticipated all more recent work by his own publications on this subject and Broun's law must be recognized as an addition to meteorological science whose importance we have only lately realized.

The results of meteorological and magnetic observations at the observatory of General Sir Thomas M. Brisbane at Makerstoun, in Scotland, are published as Volumes XVII (1845), XVIII (1848), and XIX (1849). These observations and discussions are almost wholly due to J. Allan Broun. In Vol. XVII, page 300 of the record for 1843, Vol. XVIII, pages 439–441, for the discussion of the observations of 1844, and in Vol. XIX, Part II, pages 102–104 of the general discussion of the results for the whole four years, 1843–46, Broun gives a continuous series of harmonious tables discussing several thousand observations on each particular kind

of cloud according to Howard's nomenclature. His classification by quadrants shows that the same law holds good for all directions as well as for all kinds of clouds, viz, for all altitudes. Combining the four quadrants, his figures show that the lower scud is inclined outward to the wind by 14.5°, the cirro-stratus current is inclined 22.8°, and the current of the true cirri is inclined outward 29.6°. Having, from his wind observations, found that the average or resultant direction of the surface wind at Makerstoun is from the point west 21° south, it follows that, in general, the resultant scud is from west 7° south, the cirro-stratus from the west 2° north, and the cirrus proper from west 9° north. Broun includes cumulus with scud.

The law deduced by Broun for Makerstoun, i. e., that the upper currents are deflected to the right of the lower, has a general application to the whole Northern Hemisphere.

## SEASONAL FORECASTS IN INDIA AND AMERICA.

During the past fourteen years the meteorological office at Calcutta has regularly published in May or June a memorandum giving all the accessible data relative to recent snowfall, rainfall, pressure, temperature, and wind that seemed in any way to bear upon the possibility of forecasting the probable character of the approaching southwest monsoon winds and rains. Such seasonal forecasts can undoubtedly be utilized by many classes of citizens, and the extent to which they are so used must depend largely upon the accuracy with which the season can be forecast.

The memorandum and monsoon forecast for 1898 was published on June 3 of this year by Mr. John Eliot, Meteorological Reporter to the Government of India.

The following is a summary of the chief features of the meteorology of India during the past six months, which are most likely to influence the advance of the monsoon currents and the distribution of the monsoon rainfall:

1. The snowfall of the past winter has undoubtedly been much less than usual over the whole of the western Himalayas and probably also in Afghanistan. It was probably in local excess in Chitral and perhaps in Baluchistan, due chiefly in the latter area to heavy precipitation in December and March. There was a heavy and somewhat abnormal fall in the second week of May over the whole of the western Himalayas (as was also the case in 1883, 1884, and 1888).

2. The pressure conditions in India during the past five months were such as accompany higher temperature in northern India and less snowfall than usual in the western Himalayas, and probably also the eastern Himalayas. The chief features, which have been remarkably persistent, are (*a*) general deficiency of pressure, (*b*) local deficiency in northern India and Burma, most marked in Bengal and Burma, and (*c*) local excess in western India, greatest in Sind, Kathiawar, and the Konkan.

3. The temperature conditions during the past five months are such as usually accompany a more open and drier winter than usual (with scanty snow) in the Himalayan area. Temperature was largely in excess in April and in moderate excess in May. The excess in these months was, on the whole, most pronounced in northwestern India and the north Deccan.

4. The air has been throughout nearly the whole season much drier than usual and skies remarkably free from cloud.

5. The air movement was more vigorous than usual in March and April, due to the intensified thermal conditions of the period in the interior of India.

6. Hence, the snowfall in the Himalayan area has been of such a character as not to impress any conditions upon the pressure distribution, temperature, and air movement in northern and central India unfavorable to the early or full extension of the monsoon currents in their progress northward from the equator.

It may be noted that some of the abnormal features of the meteorology of India during the past seven months have been related to abnormal conditions prevailing in Persia and southeastern Europe. Anticyclonic conditions obtained to a most unusual degree in southern Europe from November onward, and, as a consequence, cool, dry, northwest winds prevailed in Persia with remarkable persistence from November to February. This abnormal air movement extended across Baluchistan and the north of the Arabian Sea into northwestern India, and has undoubtedly contributed to the unusual dryness of the air and freedom from cold-weather storms of the period in northern and central India.

After discussing the special features of the weather and monsoons since 1879, Mr. Eliot makes a detailed forecast for the southwest monsoon and rains of 1898, as follows:

The southwest monsoon rains will probably commence not later than the end of the first week of June on the coast of Bombay and the third week of June on the coast of Bengal. As to the quantity of rainfall, the general conclusion is that the rainfall may be deficient to a slight or moderate extent, depending chiefly upon the strength of the monsoon in Sind, Cutch, the north and west Punjaub, and west Rajputana; that it will very probably be at least normal in amount in central India and the northern half of the Peninsula, except, perhaps, Berar, Khandesh, and the west Deccan, and may be in moderate excess in the eastern half of the northwestern provinces, Bihar, the central provinces, and the eastern states of central India. It will probably be normal or in excess in Burma, Assam, and perhaps in east and north Bengal, and may be in slight defect in west Bengal.

In nearly all parts of the world the rainfall goes hand in hand with the distribution of pressure and wind, and, in fact, follows after these. It would not be surprising, therefore, if we should eventually be able to do for portions of the United States as well as Blanford and Eliot have done for India.

## EARTHQUAKES IN NEW BRUNSWICK.

Mr. Samuel W. Kain has published in the bulletin of the Natural History Society of New Brunswick a list of all the earthquakes on record in that Province, together with such details of each as seem worthy of preservation. The following list of dates is taken from his work:

The times given by him are those of St. John local time, which may be reduced to seventy-fifth meridian time by subtracting 35′ 44″.

1663, February 5, 5:30 p. m. to 8 p. m.
1755, November, on several dates.
1764, September 30, about noon.
1817, May 22, 3:31 a. m.
1824, July 9.
1855, February 8, 6:30 a. m.
1860, October 17, 6:25 a. m.
1869, October 22, 5:48 a. m.
1870, March 17, 6 to 8 a. m.
1870, October 20, 11:40 a. m.
1882, December 31, 9:56 p. m.
1884, January 26.
1885, June 10, 10 a. m.
1896, March 22, 7:56 p. m.
1896, May 15, 11 p. m.
1897, January 26, a. m.
1897, January 28, 9 p. m.
1897, February 14, 9 p. m.
1897, September 25, 1:30 p. m.
1897, October 12, 10:35 p. m.
1898, January 11, 2 a. m.

Concerning each of these Mr. Kain gives such other details as are accessible to him, and will, of course, be pleased to hear from those who can add to the list. He notes the great frequency of earthquakes at Grand Manan, and that shocks are of frequent occurrence in the Bay of Fundy, where they are generally spoken of as the reports of cannon. In regard to this point, Dr. George F. Matthew said:

This part of the Bay of Fundy is remarkable for its great depth and precipitous shores. Off Brier Island the bottom descends to a depth of 100 fathoms in a distance of three miles from the outermost ledge; it is almost equally abrupt on the Grand Manan slope; the trough between is deeper than the bottom of the Gulf of Maine outside adjoining. This is the only part of the Bay of Fundy where there have been heavy outflows of trap of Triassic age on *both* sides of the bay, and the abyss between may be complementary to these ejections of lava. The weakness of the earth's crust here in Triassic times, as shown by the volcanic eruptions of that age, may not even yet be altogether removed; but the greater tendency to earthquake movements in this district may be the dying throes of the old Triassic disturbances.

## RECENT EARTHQUAKES.

Prof. E. W. Morley, at Cleveland, Ohio, and Prof. C. F. Marvin, at Washington, D. C., report no disturbance on their seismoscopes during the month of June. The following ad-